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Original Article

INFLUENCE OF MOISTURE ABSORPTION AND THEIR EFFECT ON THE PHYSICO-MECHANICAL PROPERTIES OF COIR-LUFFA FIBRE REINFORCED POLYMER MATRIX COMPOSITES

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ABSTRACT

Mechanical properties of fiber reinforced polymeric materials are significantly more essential under the various environmental condition due to higher aging resistance and durability. Composite specimens containing luffa mate, short coir fiber with different fiber length and content were developed by simple hand lay-up method. Water retention test was conducted by the submersing specimen in distilled water for a variable time period till they achieve their saturation state. The specimen was soaked in normal water for 10 days before testing to decide the impact of water absorption on the mechanical properties. The specimen was tested for reference without water immersion. The hardness, voids, tensile strength, flexural strength and impact strength behavior of water immersed specimen were conducted and compared with that of without water immersion specimens as per ASTM standard. A considerable loss in the physical and mechanical properties of coir-luffa fiber composites is observed after water absorption. Moisture absorption leads to the degradation of fiber-matrix interface region creating poor stress transfer efficiencies resulting in the reduction of mechanical and dimensional properties.

Fracture surfaces of dry and wet sample of composites were observed by Scanning electron microscope.

KEYWORDS: Luffa Fiber, Coir Fiber, Water Absorption, Mechanical Behaviors & SEM

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1. INTRODUCTION

In fiber reinforcement polymer composites, the reinforcements are either synthetic or natural fibers. Synthetic fibers are made from synthesized polymer or small molecules. The compound used to make this fiber come from raw material such as petroleum-based chemicals or petro chemicals. Nowadays, the natural fibers have a great attention as they are a substitute to the exhausting petroleum sources. Among all reinforcing fibers, natural fibers have increased substantial importance as reinforcements in polymer matrix composites. The benefits accompanying with the usage of natural fibers as reinforcement in polymers are their availability, biodegradability, low energy consumption, non-abrasive nature and low cost. In addition, natural fibers have low density and high specific properties. The specific mechanical properties of natural fibers are equivalent to those of synthetic reinforcements. Natural occurring fiber-based composites pay attention for making ecological suitable engineering materials, consequently, it has forced manufacturing industries such as automotive, construction and wrapping to replace new materials that can substitute rather than conventional non-renewable reinforcing materials such as carbon fiber, glass fiber. The main advantage of naturally occurring fibers over synthetic fibers is suitable as low density, bio-degradable, cost-effective, good specific strength and modulus. Natural fiber occurring based

reinforced polymeric composites have also some drawback such as the unsuitability between the hydrophilic (natural fiber) and hydrophobic thermoplastic and thermoset matrices.

Composite reinforced with cellulose-based fiber and fiber reinforced composites- materials, manufacturing, and design has been studied by [1, 2]. The enhancement of the adhesion between fiber and the matrix which is the suitable use of physical and chemical treatment is required [3]. Coir is a natural fiber extracted from the husk of the coconut fruit which contains coir fiber and a corky tissue called pith. Coir fiber is produced in large quantities and absorbs water easily [4]. Luffa is the most cost-effective and broadly used materials. It is essential that the composites retain their mechanical properties with less degradation in the water or moisture environment. It is believed from the water environment the water molecules will enter quickly the interphase of the composites between the fiber and resin because of the capillarity.

The percentage of moisture uptake increased as the fiber volume fraction increased due to high cellulose content. The tensile and flexural properties of hemp fiber reinforced unsaturated polyester composites specimen were found to decrease with increase in the percentage of moisture uptake [5]. A decrease in the tensile properties of the composites was demonstrated, indicating a great loss in the mechanical properties of the water-saturated sample compared to the dry sample. The percentage of moisture uptake was also increased as the percentage of fiber weight increased due to high cellulose content [6]. Moisture absorption leads to the degradation of fiber-matrix interface region creating poor stress transfer efficiencies resulting in the reduction of mechanical and dimensional properties. Impact strength is an important property that provides a sign of overall materials toughness. The impact strength of fiber reinforced polymer is governed by the matrix-fiber interfacial bonding and the properties of both matrix and fiber. After composites endure a sudden load, the impact energy is dedicated to the combination of fiber pull-outs, fiber rupture and matrix deformation [7]. Generally, impact strength increases as fiber content increases in fiber reinforced polymer composites because of the increases in fiber pull out and fiber breakage [8].

The present study investigates the effect of fiber length and fiber content on the water absorption behavior of luffa fiber reinforced epoxy composites with a different percentage. The work done by the author to study the effect of water absorption on the mechanical properties of coir-luffa reinforced hybrid polymer composites and comparative analysis before and after absorption is new since no literature is available as per searching by the author.

2. MATERIAL DETAILS AND COMPOSITE FABRICATION

Short coir fiber and luffa mate are taken as a reinforcement and epoxy as matrix materials in the current study. Both fibers (short coir fiber and luffa mate) are collected from local sources. The epoxy resin LY-556 and the corresponding hardener HY-951 is procured from Ciba Geigy India Ltd. The fabrication of the composite slab was carried out by conventional hand lay-up technique. The low temperature curing epoxy resin and corresponding hardener were mixed within a ratio of 10:1 by weight recommended by the manufacturer. Composite with different fiber loading (20 and 25 wt.%) in which luffa mate content are fixed 10 wt.% and different fiber length (15, 20, 25, 30 and 35 mm) were fabricated and subjected to post curing at room temperature for 24 hours. Short abbreviation used in the present work is summarized as: WA as Without absorption and AWA as along with water.

2.1. Water Absorption

In the present study, moisture absorption studied were performed according to ASTM D570-98 standard test method for moisture absorption of plastics. The samples were taken out periodically and after wiping out the water from

the surface of the sample weighted immediately at 24, 24, 72, 96 120 hours. The moisture absorption was calculated by the weight difference. The weight gain in percentage of the samples was measured at a regular time interval of time by using the following equation:

$$\text{water absorption}(\%)=\frac{W_n-W_d}{W_d} \tag{1}$$

Where W_n is the weight of composite samples after immersion and W_d Is the weight of the composite sample before immersion

2.2. Mechanical Testing

Micro-hardness is done using a Leitz micro-hardness tester. A diamond indenter in the form of a right pyramid with a square base and an angle 136° between opposite face is forced into the materials under a load F.

The two diagonal X and Y of the indentation left on the surface of the materials after removal of the load are measured and their arithmetic mean L has calculated. in the present study. The load considered is F=50 gm.

Vickers hardness number is calculated using the following equation.

$$H_V = 0.1890\frac{F}{L^2} \text{ and } L=\frac{X+Y}{2} \tag{2}$$

Where F is the applied load (N), L is the diagonal of square impression (mm), X and Y is the horizontal and vertical length (mm). The void content of composite sample has been determined as per ASTM D-2734-70 standard procedure. The tension test is generally performed on flat specimens. The most commonly used specimen geometric is a dog-bone specimen. The tensile tests were conducted according to the ASTM D 3039-76 standard on a computerized universal testing machine INSTRON. The spam length of the test specimen used was 42 mm. The test was performed with a constant strain rate of 2 mm/min.

The flexural test was performed using 3-point bending test according to ASTM D790-03 standard procedure. A specimen of 150 mm length and 15mm wide were cut and were loaded in the three-point bending test. The specimens were tested at a crosshead speed of 5 mm/min. The test was conducted on the same machine used for tensile testing. The flexural strength was found out by using the following equation.

$$F.S = {}^{3FL}\!/_{2bt^2} \tag{3}$$

Where F is the maximum load (N), A is the cross-sectional area of the sample, L is the distance between the supports (mm); b is the width of the specimen (mm) and t is the thickness (mm). Low velocity instrumented impact tests are carried out on the composite specimen. The pendulum impact testing machine ascertains the notch impact strength of the materials by shattering the v-notched specimen with a pendulum hammer, measuring the spent energy and relating it to the cross-section of the specimen. The standard specimen size as per ASTM D 256 is 64mm × 12.7 mm × 4mm, and depth of the notch is 10mm. respective values of the impact energy of different specimen are recorded directly on the dial indicator.

3. RESULTS AND DISCUSSIONS

In this study, the results from the experimental the results are grouped into two parts as follows:

Part 1: Evaluation of water absorption behavior of coir-luffa polymer composites

Part 2: Effects of water absorption at room temperature on the mechanical properties

3.1. Water Absorption Behavior

The effect of fiber loading and length of fiber on the water absorption behavior of coir epoxy composites added with luffa mate with an increase in immersion time is shown in figure 1. It has been observed from the experimental investigation over the water aging behavior of hybrid composites that the rate of water absorption of the composites increases with increase in immersion time. The obtained results has been shown in figure 1. It is further observed that after a certain value of water absorption, a saturation point will be reached and consequently no more water absorption takes place at that point of saturation. The similar type of results has been obtained in reference [9] which validates the present study shown in figure 1. The reason may be due to the increase in the number of free OH group of cellulose as the content of natural fiber increases in the composites. This increase of free OH group is because of coming in contact with moisture and form hydrogen bonding and result in weight gain of the composites. It may also be inferred from figure 1 that E_2 composites (i.e. with 25 wt. % fiber loading and 35 mm fiber length) have maximum water absorption. The reason may be due to the presence of a large amount of fibers and void which absorb more water in the composites. Composites A_1 (having 20wt.% fiber loading and 15 mm fiber length) exhibits minimum water absorption rate in comparison to all the composites fabricated. This is due to the presence of less fiber and voids of the composite.

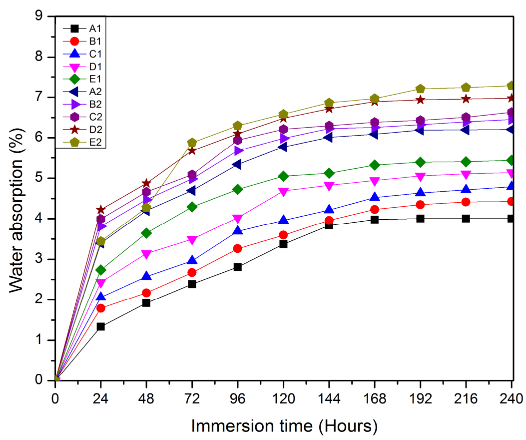

Figure 1: Water Aging Behavior of Hybrid Composites

3.2. Effect of Water Absorption on Mechanical Properties

In this section, the studies are done for the effect of water absorption on the mechanical properties of coir-luffa polymer composites after placing the specimen in water at room temperature and comparing them with a normal sample.

3.2.1. Hardness, Density and Void Formation

The effect of jute fiber and luffa mate on the hardness of the polymer composite is presented in Table 2. The hardness of polymer composites reinforced with different fiber length and fiber content increased from 19.45 Hv to 32.22 Hv respectively. This increase in hardness is because of the distribution of the test load on the fibers. The

distribution reduces the surface area of penetration and so the hardness increases and causes better precision. It is observed by table 2 that hardness is affected by water absorption. It is also observed that hardness decreases in all coir-luffa fiber reinforced sample in wet condition. The hardness of the coir fiber reinforced composites decreases as the water absorption increases. It is observed that the deformation depth increases for water-immersed specimen compared to dry one, due to the hydrophilic nature of fibers and led to the deformation of a weak fiber-matrix interface. The results also agree well with the results of Al-Mosawi Ali [10] and by other researchers working with natural fiber based composites [11, 12].

Table 2: Comparisons of Hardness and Voids Value of WA and AWA Based Composite

Simple	Hardness (Hv) of WA	Hardness (Hv) AWA	Void Content (Vol %) WA	Void Content (Vol %) AWA
A_1	19.45	18.78	0.945	1.026087
B_1	21.87333	19.85833	1.605	1.8115942
C_1	22.29667	20.26667	2.182	2.3137691
D_1	25.31667	23.03333	2.328	2.6358411
E_1	26.51667	24.85	3.178	3.5968379
A_2	22.78333	19.22333	1.887	2.0154418
B_2	23.61667	22.27	3.909	4.2088206
C_2	25.46667	23.73733	4.492	4.8091429
D_2	30.55	25.26613	6.045	6.3569617
E_2	32.22333	28.0804	7.753	7.845249

3.2.2. Tensile Strength

In this section, the studies are done for the effect of tensile strength of coir-luffa polymer composites. Fabrication of composites plays a vital role on the strength. The experiment has been done to study the tensile strength and results were obtained for both dry and water aged samples. The obtained graph are linear up to the point of failure which is shown in Figure.2

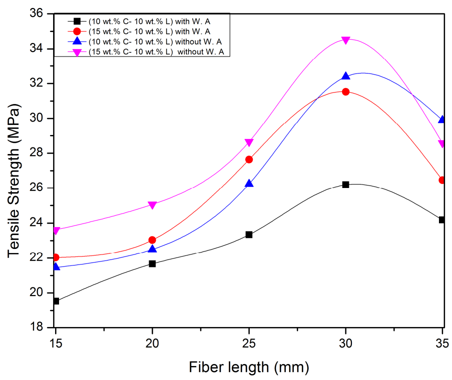

Figure 2: Variation in Tensile Properties with the Effect of Fiber Content and Fiber Length

It is observed that the tensile strength gradually increases with the increase in fiber length and reaches to a maximum value of 34.54 MPa at 30 mm fiber length in dry condition. It concludes a lower value at a greater length of fiber i.e. 35 mm. Fiber length is the important parameter for short fiber reinforcement which effects the properties of the composites. It is observed by experimental result that in case of small fiber length, tensile strength is less. The reason may be that length may not be sufficient for proper distribution of load. On the other hand, tensile strength decreases for longer fiber length. The cause of the reduction of strength may be fiber entanglement. This may be observed by the results and consequence drawn by literature reference [13-14].

The effect of water absorption on the tensile strength of coir-luffa fiber reinforced polymer composite is also shown in figure. 2, which shows a considerable decrease in the tensile strength of wet samples compared to the dry samples. The reason for this is that in the wet sample absorbed water molecules and reduced the intermolecular hydrogen bonding between cellulose molecules in the fiber established intermolecular hydrogen bonding between the cellulose molecules and water molecules in the fiber, thereby reduced the interfacial adhesion between the fiber and the matrix [15].

3.2.3 Flexural Strength

In this section, the studies are done for the effect of fiber length and content on the flexural strength of normal coir-luffa polymer composites. The results obtained is presented in figure. 3. It is observed that flexural strength increases as fiber content increased at 25 wt. % and 35 mm fiber length in the normal condition. The consequence is drawn from the figure 3 that the flexural strength of luffa-coir polymer increased from 31.64 Mpa to 60.13 Mpa. The reason for the increase of flexural strength may be because of the increased fiber length and content of coir-luffa polymer composites and also due to the ability of the natural fiber. This is also due to resisting properties of bending force and good stress transferability from the matrix interface. This results to improve the strength properties. This above result are also exhibited in the literature reference [16] which agrees well with this work of flexural strength of coir-luffa fiber based composites.

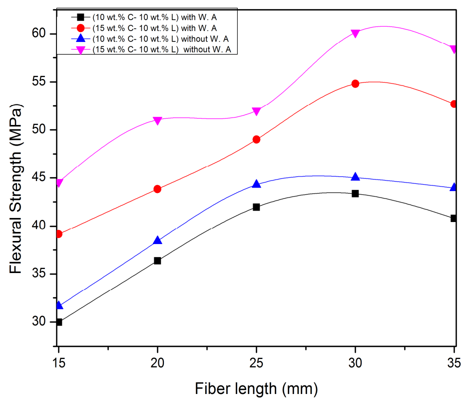

Figure 3: Variation in Flexural Properties with the Effect of Fiber Content and Fiber Length

Variation in flexural properties with the Effect of fiber content and fiber length has been done in the subsequent section after water absorption. The effect of water absorption on flexural strength of coir-luffa polymer composites is presented in figure 3. It can be concluded by the figure 3 that the flexural strength of composite decreases after water absorption. The flexural strength characteristics decrease in wet composites as compared to dry composite sample since the immersion of the composite sample in water affects the interfacial adhesion between fiber and matrix. The Same trend of Physical, mechanical, and water absorption behavior of coir/glass fiber reinforced epoxy based hybrid composite has been observed by Bhagat et al. [10].

3.2.4. Impact Strength

In this section, the studies are done for the impact strength of coir-luffa polymer composites and the results has been shown in figure 4. It can be observed from figure 4 that impact strength rapidly increases up to fiber content 25 wt. %

at 35 mm length in the dry sample because the presence of luffa mat increases the ability of these composites to absorb impact energy. The addition of luffa fiber and coir fiber from 10 wt. % to 15 wt. % increases the impact strength from 15.87 kJ/m^2 to 31.75 kJ/m^2 respectively in dry condition.

The consequence can be drawn from figure 4 that the decrease in impact strength after water immersion technique can be linked to the weak fiber-matrix interface. It results the reduction of the mechanical properties and dimensional stability of composites which agree well with the results drawn in the reference of Sahib and Jog [17].

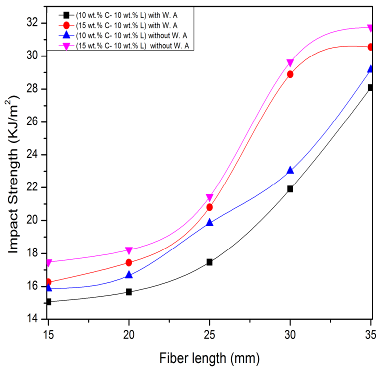

Figure 4: Variation in Impact Properties with the Effect of Fiber Content and Fiber Length

3.2.5. Morphology Study

Figure 5 a-b shows the micrographs of the fractured specimen after tensile test in both dry and wet condition. SEM micrograph specifies the phenomenon of 'pull-out occurred to a greater extent causing the failure of materials. The image analysis also shows the formation of voids due to fiber pull-out, de-bonding, breakage. Overall, a larger amount of broken fibers was observed if compared to the numbers of voids associated with the fiber pull-out [18].

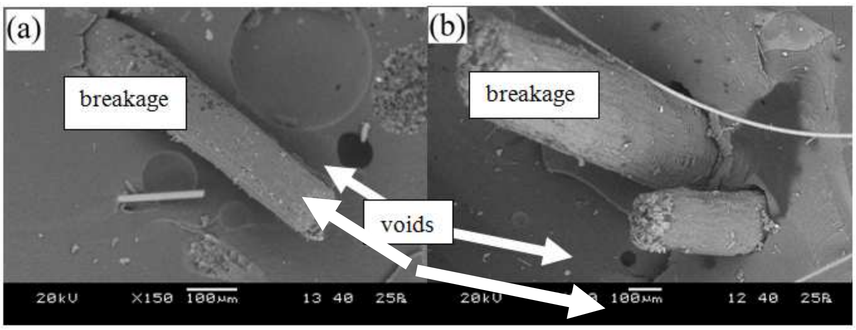

Figure 5 (a-b): SEM of Coir-Luffa Reinforced Polymer Composite after Tensile Test

At some region, weak fiber-matrix adhesion was observed, which can be attributed to low compatibility between hydrophilic nature of fiber and hydrophobic nature of matrix used. Figure 5(a) represents the wet fractured specimen, whereas figure 5(b) shows the dry fractured specimen after the tensile test. It has been witnessed from the figure that more void created in a wet type of fractured specimen. The fiber breakage, tearing of fibers and pull-out were detected from fractrograph. The voids and fiber entanglement were also found due to poor blending quality. These defects may act as crack tip leading to matrix cracking portant or, in the second thing, resin reach areas that leading failure of the composite bond. In the case of dry fractured test, fewer voids occur.

4. CONCLUSIONS

The following conclusions can be drawn from the experimental results of the coir-luffa composites which is summarized as below:

- The water aging behavior of hybrid composites that the rate of water absorption of the composites increases with increase in immersion time. After a certain value of water absorption, a saturation point will be reached and consequently no more water absorption takes place at that point of saturation. E_2 composites (i.e. with 25 wt. % fiber loading and 35 mm fiber length) have maximum water absorption.
- Hardness decreases in all coir-luffa fiber reinforced sample in wet condition. The hardness of the coir fiber reinforced composites decreases as the water absorption increases. The deformation depth increases for water-immersed specimen compared to dry one.
- The tensile strength gradually increases with the increase in fiber length. Flexural strength increases as fiber content increased at 25 wt. % and 35 mm fiber length in the normal condition. The flexural strength of composite decreases after water absorption. The flexural strength characteristics decreases in wet composites as compared to dry composite sample.
- Impact strength rapidly increases up to fiber content 25 wt. % at 35 mm length in the dry sample. The addition of luffa fiber and coir fiber from 10 wt. % to 15 wt. % increases the impact strength from 15.87 kJ/m^2 to 31.75 kJ/m^2 respectively in dry condition. After water absorption, SEM image of the composites confirms that coir has a great tendency of swelling and absorb more moisture.

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